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TECHNOLOGY:

Key to Progress

TECHNOLOGY Holds Key to U.S. National Security

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The vital role which technology plays in lives and in the world is the purpose for discussing "Technology: The Key to Progress". The United States is a nation which has a tradition of technological initiative and superiority. Today, the United States possesses technological superiority over the rest of the world, but looking to the future, there appears to be some causes for concern. If this Nation is to maintain its traditional preeminence and leadership in technological affairs, it shall have to renew its national commitment. The theme is "Technology: The Key to Progress"—hence, consider the following:

- The necessity of technological leadership.
- Some disturbing trends.
- The future.

Necessity of Leadership

Technological leadership involves much more than just good science. It takes innovative engineering, sound management, thorough planning, a healthy research and development establishment, access to resources, and a quality production and marketing system. All of these factors are prime contributors to real national security. They represent America's true strength in this modern world. One can observe that the United States has technological leadership, and can agree that this leadership must be kept to maintain the standard of living and security. It is clear though, that technological superiority is a transient thing which requires continual reestablishment. For example, consider the U.S. inroads on the Swiss virtual monopoly in watchmaking. The productivity and development of new devices by various U.S. firms have made possible electronic timekeeping and display which have changed the market place considerably in the past five years.

Clearly, technology can be used for good or for evil—but the problem is not quite that simple. Technology will be used for good and evil. It defends freedom and kills innocent people. It creates stimulating new careers and boring assembly line jobs. There is a tendency, in some circles, these days to emphasize the negative aspects of technology. Perhaps the situation is best described by the observation that in the management of technology people have, at times, been poor workmen and, like all poor workmen, tend to blame the tools instead of themselves.

But face it, technology not only shapes lives, it supports our very existence. The world could not support its present level of population without technological aids to the production, preservation, and distribution of food needs. It does no injustice to the medical profession to observe that increased life span is mainly connected with the fact that people no longer work themselves to death. It is no exaggeration to say that technology has removed the economic justification for slavery.

Although the social ramifications of technology are well known, consider the following:

- By world-wide standards of even a few generations ago, no American is poor.
- Even with all the economic and social problems, no American must starve to death or freeze because of lack of clothing or shelter.
- Technology has provided food, clothing, shelter and much more in unprecedented abundance.
- The standard of living in the United States is among the highest in the world. U.S. workers earn three and one-half times the income of French workers and two and one-half times that of Japanese workers. labor costs. In brief, higher productivity is achieved through technological superiority.

As observed before, American lifestyle is based on the freedom of each individual to pursue his own goals in accordance with his abilities and his own choices. This system, however, requires the stability of perceived national security in order to flourish, and it is the classical task of the military to provide that security. In this sense, extant technology—that is, deployed systems—is what provides that security and stability, and the exploitation of high technology enables the retaining of relative military stature without maintaining an unduly large force of men and weapons. In the trade-off between quantity and quality, the United States has opted for quality.

In the past, the Soviet Union, a principal potential adversary, has emphasized quantity although there is a reverse trend discernable today, and

Technology plays a vital role—whether it be combining microwave energy, infrared, and steam pressure systems to cook a roast in an experimental omni-oven at the Army's Natick Laboratories, (right), or analyzing the structural response of highly-stressed turbine engine blades and discs by the use of Holography. On the cover is an experimental circular terrain model which adds realism to a simulated remotely-piloted vehicle mission.

this trend, fostered by a massive commitment to defense Research and Development (R&D), is particularly disturbing. R&D per se, is not, of course, security, but it does provide those tested ideas which can lead to quantum improvements in operational capabilities. The USSR is strongly emphasizing military R&D all the way from the education of engineers and scientists through the construction of specialized facilities and, finally, to the production of sophisticated weaponry. Their total annual commitment of resources now exceeds that of the United States and rises with each year.

The United States retains overall technological superiority today, but there are important areas in which the Soviets lead—such as integral rocket-ramjets, Magneto Hydro Dynamics (MHD) energy conversion, chemical warfare and certain aspects of metals manufacturing such as electroslag and plasma arc remelting. The Soviets are not likely to change their commitment, and the United States does not seem likely to increase the number of men and weapons deployed to compensate for the new challenge.

The closed nature of the Soviet society makes it possible for them to pursue developments in secret. This fact makes it doubly important for the United States to maintain the scientific lead to enable the assessing of their developments from the fragmentary evidence which seeps through the wall of secrecy. Timely assessments are necessary to prevent

This exotic research laser "mixes" an optical beam and an acoustic wave to produce a new light beam. It is called a tunable laser because its wavelength can be changed or "tuned" electronically to span certain portions of the visible spectrum.

surprise and enable the United States to react appropriately.

Some Disturbing Trends

But, there are challenges and dangerous trends in other quarters as well. Examine some quantitative trends:

- The United States accounted for 75 percent of the free-world R&D in 1961, but less than 66 percent in 1969, and the downward trend persists.

U.S. total R&D is about equal to that of the Union of Soviet Socialist Republics, but 60 percent of theirs is devoted to military, space and atomic energy versus 45 percent in the United States.

- Technical manpower—1965-1970:

France and USSR expanded by 9.5 percent per year.

Japan by 4.5 percent.

U.S. by 3.9 percent.

U.K. by .2 percent.

The USSR is graduating twice as many scientists and engineers as the United States and now has more than the United States. In contrast, U.S. freshman enrollment is 35 percent below the 1967 level.

- The defense industry's inability to attract and retain young engineers is particularly serious and has dangerous long-range consequences. The average age of technical personnel in 17 aerospace companies surveyed last year was 43.

World trade follows technology efforts and innovation. At the present time, the United States has a favorable trade balance only in agricultural and technologically intensive products. In the case of technology intensive products, the balance decreased by 30 percent since 1965. All around us we see extensive market penetration by foreign products:

- Imported steel which represented 5 percent of our consumption in 1962 represented 17 percent in 1972.
- Imported autos which represented 5 percent of U.S. consumption in 1962, represented 15 percent of the market in 1972.
- Imported textile products which represented 2 percent of the textile market in 1962 now represent 10 percent of the market.
- Imported consumer electronics accounted for 35 percent of the U.S. market in 1962 and a staggering 72 percent in 1972.

The picture in electronics is particularly disturbing since modern electronics is based on 16 innovations developed since World War II. It started with Bell Labs discovery of the transistor effect in 1947 and has progressed through:

- The point contact transistor.
- The alloyed junction.
- The grown junction.
- Zone refining.
- Chemical etch processing.
- Epitaxy.
- The planer process.
- The Gunn effect.
- Beam lead technology.
- The Metal Oxide Semiconductor (MOS) transistor and integrated circuit.
- Large Scale Integration (LSI).

Of the sixteen innovations, 12 were accomplished exclusively in the United States. Two, the diffusion process and the integrated circuit, were accomplished independently in the United States and abroad; while only two, the tunnel diode and perhaps III-V compounds, were done exclusively abroad. U.S. trade, production and domestic consumption of non-defense electronics and communications equipment had a favorable balance of $200 million in 1965 but a $953 million deficit in 1972.

Innovation, as measured by patents, shows another disturbing trend:

- In 1965, U.S. patents issued to foreigners were 25 percent of those issued to U.S. citizens. In 1972, U.S. patents issued to foreigners were 45 percent of those issued to U.S. citizens.
- The greatest growth in foreign patents has been in metallurgy, electronics, chemicals, automotive, and textiles. In the latter two areas, foreign patent activity in the United States equals or exceeds that of this country.

It is also disturbing that the export of U.S. technology seems to be accelerating. This trend is difficult to measure, but:

- U.S, receipts from foreign countries for royalties and licenses exceeded U.S. payments for such items by a ratio of 8:7 (1972). This represents a 16 percent increase since 1965. It is believed that this mostly one-sided transfer of U.S. technology represents a prime factor in our decreasing technological advantage. If these trends continue unabated, it seems plain that the United States will fall behind in innovation, in trade and in economic growth.

Technology also contributes to productivity. Of course, other factors such as experience in manufacturing, availability of capital, supply of services, diffusion of technology, and public support that encourages and adapts to change also contribute. While the logic is not the purest, the fact remains that countries with the highest research and engineering activity per sales dollar during the 1960s also had highest increase in productivity. Japan, Sweden and the Netherlands had R&D growth rates of 5 percent per year. Unfortunately, the United States—of the eight largest manufacturing nations—is re-investing the smallest part of its gross national product (GNP) in industrial tools, machinery and production equipment according to a speech earlier this year by the former Deputy Defense Secretary David Packard. Of their respective GNPs, the United States invested 10 percent, Germany and France invested 15 percent and Japan invested 20 percent in industrial tools, machinery and other production equipment.

As further evidence of the seeming relationship between R&D and productivity, it is worth noting that the aircraft, electrical, machinery and instrumentation industries had highest ratio of R&D funding to sales, and they had highest increases in output over a 20-year period.

There are those who try to make the case that the shifting technological balance is due to over investment in defense R&D at the expense of R&D in the civil/industrial sector. The data do not support this claim. The United States invests 1.35 percent of its gross national product in industrial and civilian R&D. This is more than that for military R&D. Only Japan and the Netherlands (with 1.4 percent and 1.7 percent respectively) exceed the United States in this respect. To this fact we must add that the commercial sector has greatly benefited—and continues to benefit—from our military programs. Computers, jet aircraft, and solid-state electronics are obvious examples and there are many others of a more subtle nature.

It is not claimed that technology is the sole source of the high productivity index which must be maintained. Experience, capital, services and even public support and expectations are equally necessary ingredients. But, if leadership is to be maintained, the technology base must clearly be maintained. Thus, in general, when selling, one should sell products—not productivity. If this nation does sell technology, she must demand a fair price and that includes the cost of developing the several options which led to the technology in question, as well as the cost of developing maintenance and repair organizations and the cost of developing the market and consumer confidence. One must also consider recovery of tax credits for development investment from licenses, royalties, and outright sales of technologies when such exports could ultimately contribute to a negative balance of trade.

Retaining Leadership

To retain U.S. technological leadership in the future, it will take much more than bigger R&D budgets and enlightened export control policies. The right technologies must be selected for effecting "order-of-magnitude" improvement in cost, performance, size, power, etc. The following list, although not exhaustive, includes conceptual breakthroughs offering "order-of-magnitude" improvement:

- Ceramic Turbines

The substitution of ceramic materials for costly, scarce superalloys in turbines should enable us to substantially raise turbine operating temperatures. This, in turn, leads to higher efficiency, smaller and less costly turbines which are not dependent on alloys which are in short supply.

- Ferrous Die Casting

Casting has been done for centuries using sand molds, a process which does not lend itself readily to automation. The use of superalloy molds, which can withstand high temperatures, together with ferrous metals in a slurry-like state, results in a process in which high temperature ferrous metal parts can be cast using reusable dies. This makes automation of this process possible and results in cast parts which, when removed from the superalloy mold, have a smooth, machine-like finish, thus obviating the need for further costly machining in many applications.

- Adaptive Optics

The natural turbulence of the atmosphere limits the fidelity of imaging through the atmosphere with optical systems. It is possible to compensate for this turbulence by sensing it and using the information to selectively deform portions of optical components, such as mirrors, in a closed loop system. The ability to adaptively compensate for atmospheric effects and component imperfections in precise optical systems makes possible telescopes with unparalleled fidelity, increased propagation range and lethality for laser beams and large diffraction limited space-based optical systems. In addition, because deformable optics allow the ability to electronically focus light (we already have the ability to electronically deflect

Atomic particles ranging in energy from 5 to 75 million electron volts are generated in the Naval Research Laboratory's cyclotron.

and modulate light), it may permit breakthroughs in the area of three dimensional optical storage.

- Infrared Charge Coupled Device Focal Plane Arrays

Charge coupled device (CCD) technology lends itself to solid-state image sensing and analog signal processing. It is not included in this compilation because it doesn't represent an "order-of-magnitude" improvement. However, the extension of this technology to the infrared (IR) using extrinsic silicon for IR detection married on the same chip with silicon CCD signal processing makes possible IR imaging systems with several orders of magnitude more detection than present systems. This results in much greater resolution and sensitivity as well as greatly simplified signal processing. This technology could extend IR early warning to tactical missiles and aircraft, in addition to providing ground-based FLIRs (Forward Looking Infra Red) of lower cost and greatly improved performance.

- High Energy Chemical Lasers—

High energy lasers which are powered by chemical reactions rather than high voltage discharges result in systems of greater effeiviency and smaller size. Such systems could be deployed in space as well as on the ground.

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- Computer Software

The DoD spends over three times as much for computer software (over $3 billion/year) as it does for hardware. It now appears possible to optimize software for verification, analysis, specification, documentation and maintenance through enlightened programming discipline and the judicious selection of the programming language. It is also possible, through computer networking, to make advanced programming tools widely available to programmers who would ordinarily not have them at their disposal. Thus, for the first time, a degree of standardization and control over the software process may be possible, turning what is now an art into a science. A bit further in the future is automatic programming using the computers themselves to write programs whose functions and performance objectives are carefully specified to the machine.

- Acoustic Array and Signal Processing Technology

The ocean is not a non-linear medium. It has been found that it is a linear time variant medium with the coherence times on the order of 20-30 minutes. This means that acoustic arrays an order-of-magnitude larger than those presently in use are possible. Increased array gain, coherent signal processing and multi-array correlation result in the possibility of substantial improvement in the ability to detect submarines.

- Solid Electrolyte Batteries—

Liquid electrolyte batteries are inferior to solid electrolyte systems; however, the solid electrolyte systems require high temperatures for operation. The discovery of efficient room temperature solid-state electrolytes such as $Li_{2.4}T_{13.4}O_8$ promise solid electrolyte batteries which have energy densities of greater than 100 watt-hours per pound. This is eight times greater than lead-acid batteries and three times greater than silver-zinc systems.

- Laminar Flow Vehicles—

It has been found that it is possible to greatly reduce the drag on hydrodynamic vehicles by external boundary layer control and by applying advanced analytical techniques to optimize the shape of the vehicle. Bodies with substantially lower drag than conventional bodies have been demonstrated. By lowering power requirements for a given speed and vehicle size, this discovery could lead to higher speed submarines and more efficient torpedoes.

- Gun Systems

Liquid propellant gun concepts are not new but have been plagued by extreme instability of the propellants and uneven combustion. The discovery of stable, storable propellants and improved understanding of propellant combustion has resulted in the demonstration of a high velocity, 75mm liquid propellant gun system. The successful development of such a system, coupled with an advanced penetrator, could lead to a 40-ton tank with high mobility/agility and, hence, increased survivability, rapid automatic loading, three-man crew, and the ability to store a larger number of rounds than current tanks. Current tanks with 105mm guns are greater than 55 tons.

- Homopolar Machines

Older homopolar machines were high current, low voltage systems requiring high magnetic fields. The discovery of new brush materials to handle higher currents, the axial segmentation of the magnetic circuit, and more efficient fluid cooling techniques could lead to an efficient, high power density (400 HP/ft^3) electric motor for ship and possible land vehicle propulsion. The SEGMAG motors appear to be superior to superconducting motors which have the additional disadvantage of a requirement for cryogenic cooling.

- Lasers

While the concept is now old, lasers are leading to conceptual breakthroughs in such areas as:

Materials processing (welding, cutting, drilling, scribing, and hardening).

Precision measurement.

Medicine where the laser scalpel with automatic cauterization permits bloodless surgery.

Communications where the laser offers wideband, jam and intercept resistant point-to-point systems.

Isotope separation (nuclear fuel preparation).

Protection and detection (security systems, etc.).

- Fiber-Reinforced Organic Matrix Composites

Composite materials have been developed to tailor-make materials that combine the advantages of two or more materials while minimizing their disadvantages. Glass fiber-reinforced organic materials, boron fiber-reinforced composites and metal-matrix composites are now in use. The most significant composites in the future are likely to be those consisting of oriented graphite fibers and/or aramid organic fiber in thermoplastic/thermosetting organic matrices. Fiber-reinforced organic matrix composites could be used in aircraft components (including helos), hydrofoils, vehicles and armor.

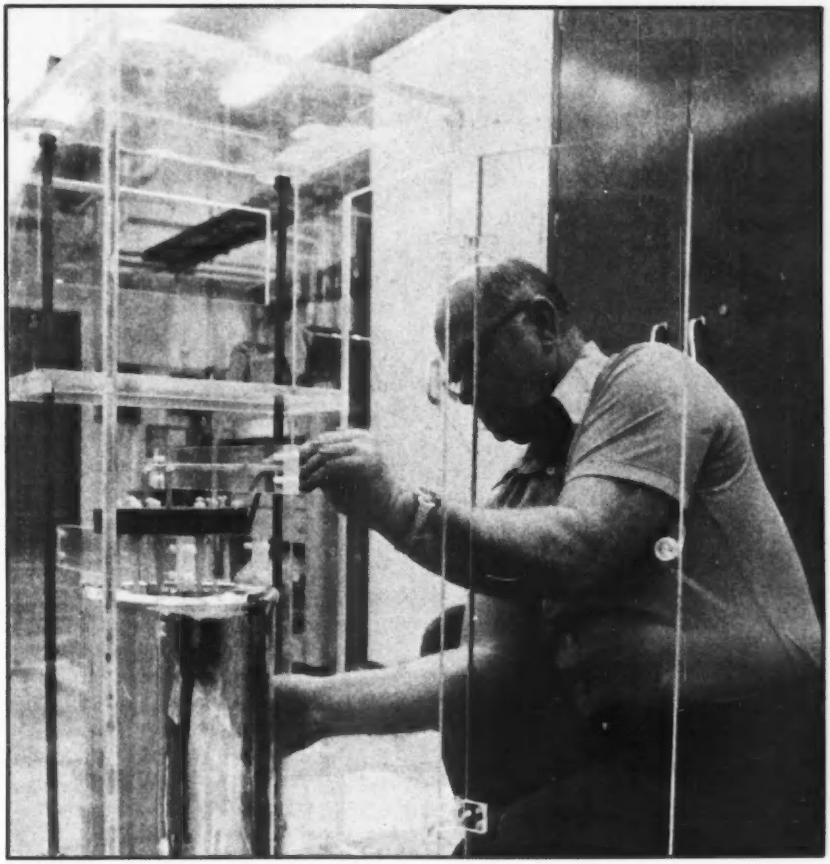
- Electroslag Remelting of Metals

Electroslag remelting involves the remelting of a metal electrode under an electrically conductive slag and solidification of the molten metal in a water-cooled mold. The higher levels of ductility, greater toughness and ease of deformation (rolling, forging, etc.) relative to conventional melted materials stem from the reduced number of inclusions and their improved morphology, the reduction of other impurities and microsegregation and favorable grain pattern. Electroslag remelted metals and alloys will find application in components subjected to severe loading conditions (e.g., complex loads involving impact and torsion) such as aircraft landing gears, tools and dies, torsion bars, bearings, armor plate, gun tubes and submarine hulls.

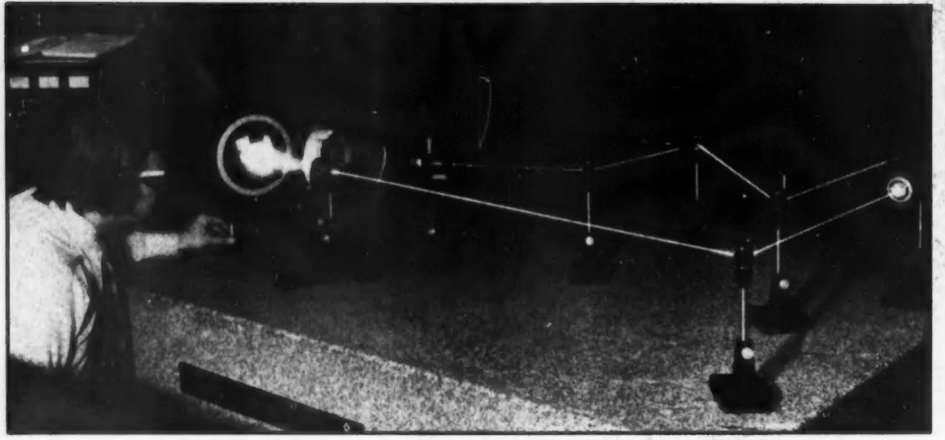
- Superconducting Electronics Devices based on Josephson tunneling in superconductors have the ability to switch in times on the order of picoseconds. The ability to fabricate arrays of such devices could form the basis for extremely high speed computer logic (in the picosecond range).

- High Density LSI (Large Scale Integration)

Photolithographic techniques used in the fabrication of integrated circuits are now capable of micron-sized definition while electron beam processing makes possible submicron geometries. This has resulted in microprocessors of 10,000 gate complexity. Better silicon material and mask improvements are enabling us to process even larger chips with even greater complexity. This is the technological basis for microprocessor and high density semiconductor memories.



The effect of transient magnetic fields on superconductors is investigated in the Air Force Aero Propulsion Laboratory.



The Holographic Lens Exposure System is used by engineers in the Air Force Avionics Laboratory at Wright-Patterson AFB, Ohio to develop new optics for laser-guided, air-to-air missiles.

- Complementary Metal Oxide Semiconductor (CMOS) Technology

The principal feature is extremely low power drain (microwatts). These devices also have a high noise immunity and can be made radiation resistant. The impact on low power, space electronics and battery powered Army field electronics is obvious. It is to be noted that each milliwatt of power saved by the Army in battery operated equipment results in an estimated one-dollar saving. Bipolar circuits require milliwatts per gate while CMOS require microwatts per gate.

- High Density Storage

Industry is making ready high density pre-recorded video systems for home entertainment. These video records, which are displayed on a TV set, have storage densities approaching 10^{10} bits per record. A record gives 30 minutes of TV viewing per side. There are two schemes for reading out the stored information which is stored in deformations in the surface of the record which can be replicated by pressing. One scheme uses a laser while the other uses capacitive sensing. A whole new concept in home entertainment based on this recording breakthrough appears to be emerging.

- Fiber Optics

Light can be guided through low-loss glass fibers in a manner analogous to the flow of current in a wire. The use of an optical carrier frequency makes possible extremely high information bandwidths and the elimination of electromagnetic interference problems. The substitution of glass fibers for copper results in much lower material costs and lighter weight. In addition to the obvious application to telecommunications, fiber optics appear to have important applications in tactical aircraft due to the lighter weight, smaller size, Electro-Magnetic Interference (EMI) resistance, opportunity for redundancy and ease of matching compared to conventional multiplex systems.

- Surface Acoustic Waves

Devices based on the generation and propagation of Rayleigh waves on piezoelectric materials are the result of interdigital transducers fabricated using techniques perfected in integrated circuit technology and high coupling coefficient materials resulting from the search for non-linear optical materials. Surface acoustic waves have wavelengths on the order of microns and propagate at the speed of sound instead of the speed of light. The interdigital transducer can be tailored to control relative amplitude and frequency. Devices based on this technology make possible compact delay lines, band-pass filters, pulse compression, correlation, transversal filters and many other signal processing functions. This represents the beginning of the functional device era where a single device performs a complex function instead of single operations such as switching, amplification, generation, modulation, etc.

The End Objective

- Does the Nation have the will to regain momentum?
- How does the nation pay for an expanded R&D effort?

Clearly, U.S. commitment and the resources the Nation is willing to devote will depend on the perceived value of the end objective. The United States will always need research on targets of opportunity—the good, the new, the little ideas—but major funding commitments require real markets or the promise of increased productivity. R&D for its own sake no longer captures the public imagination. The "markets" include those foreign markets in which the United States is not yet active as well as those areas, such as energy, environment, substitution for critical materials in short supply, and national security, in which lie our greatest problems. The United States can develop these markets through the application of technology which, as already pointed out, is not the evil some would make it. The challenge to technologists is to contribute not only scientific skills to this development, but to contribute to the public debate and understanding.

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